# FIGURE 1
## (Prior Art)

Host 1                                                           Host 2

Layer 5  ← - - - - Layer 5 protocol - - - - →  Layer 5

Layer 4/5 interface

Layer 4  ← - - - - Layer 4 protocol - - - - →  Layer 4

Layer 3/4 interface

Layer 3  ← - - - - Layer 3 protocol - - - - →  Layer 3

Layer 2/3 interface

Layer 2  ← - - - - Layer 2 protocol - - - - →  Layer 2

Layer 1/2 interface

Layer 1  ← - - - - Layer 1 protocol - - - - →  Layer 1

~110

Physical medium

100

# FIGURE 2
## (Prior Art)

210 OSI    220 TCP/IP

| | OSI | TCP/IP | | |
|---|---|---|---|---|
| 217 | Application | | ~225 | |
| 216 | Presentation | Application | | User space |
| 215 | Session | | ~224 | Software |
| 214 | Transport | Transport (host-to-host) | | |
| 213 | Network | Internet | ~223 | Firmware |
| | | | ~222 | |
| 212 | Data link | Network access | Hardware | Operating system |
| 211 | Physical | Physical | ~221 | |

FIGURE 3
(Prior Art)

← 32 Bits →

Class | | Range of host addresses

A | 0 | Network | Host | 1.0.0.0 to 127.255.255.255

B | 10 | Network | Host | 128.0.0.0 to 191.255.255.255

C | 110 | Network | Host | 192.0.0.0 to 223.255.255.255

D | 1110 | Multicast address | 224.0.0.0 to 239.255.255.255

E | 11110 | Reserved for future use | 240.0.0.0 to 247.255.255.255

<u>622 / 624</u>

FIGURE 4
(Prior Art)

Application
byte stream

400

User data

402

410

TCP
header

400

TCP
segment

412

420

IP
header

410

IP
datagram

422

430

420

Network
header

Network-level
packet



| Bit: | 0 | 4 | 10 | 16 | | 31 |
|---|---|---|---|---|---|---|
| | Source port 502 | | | Destination port 504 | | |
| | Sequence number 506 | | | | | |
| | Acknowledgment number 508 | | | | | |
| Header length | Unused 512 | Flags 514 | 516 | Window | | |
| | Checksum 518 | | 520 | Urgent pointer | | |
| | Options + Padding | | | | 522 | |

510

20 octets

402

FIGURE 5
(Prior Art)

● ●

— 32 Bits —

| Version 602 | IHL 604 | Type of service 606 | Total length 608 |
| Identification 610 | | D F M F 612 Fragment offset 614 |
| Time to live 616 | Protocol 618 | Header checksum 620 |
| Source address 622 |
| Destination address 624 |
| Options (0 or more words) 626 |

FIGURE 6A

(Prior Art)

— 32 Bits —

~602  ~604

| Version | Priority | Flow label 630 |
| Payload length 632 | Next header 634 | Hop limit 636 |
| Source address (16 bytes) 622' |
| Destination address (16 bytes) 624' |

FIGURE 6B

(Prior Art)

702

Application

Data 400

FIGURE 7

| FIGURE 7A | FIGURE 7B | FIGURE 7C |
|---|---|---|

704

TCP

402  400
| T | Data |

410

FIGURE 7A
(Prior Art)

706  IP

412  402  400
| I | T | Data |

420  708

706

422  400  422
| F | I | T | Data | F |

710  Frame relay

Physical

402  430

IP

718

| I | T | Data |

420

LLC

720

412

| L | I | T | Data |

400 440

750 402

714

722

| Frame relay | MAC |
| Physical | Physical |

760 750 402 100 760

412

| M | L | I | T | Data | M |

| F | I | T | Data | F |

430

712

724

450

FIGURE 7B

FIGURE 7C
(Prior Art)

Application — 742

400
Data

TCP — 740

402    400
T    Data

410

IP — 738

412  402    400
I   T    Data

420

LLC — 736

750    400
L  I  T    Data

412  402

440

MAC — 734
Physical — 732

750    412
M  L  I  T    Data    M

450    760    402  400

830

812 Wire Center

AR

AR 812

AR

812

800

812

R

R 814

816

LATA IP Transport Network

810

IR

Access

Routing

Interconnection

820 Existing (Layer 2) SP

Portal ISP

"Peer" ISP 820

Enterprise

FIGURE 8

External
Company

Bell
Atlantic

**IP Application**

External
Company

**IP Transport**

NextGen
Switch

Video

Web
Cache

Web
Host

V/IP
GK

eMail

V/IP
GW

AAA

Fire
wall

Chat

Yahoo

R

Sprint

R

R

R

GTE-I

R

R

R

R

R

R

SBC

R

R

UUNET

R

R

AOL

R

R

R

LATA IP NETWORK
OWNER AND/OR
OPERATOR

IP

IP

816

816

814

812a

812b

812c

810

800'

R

R

AR

AR

AR

AR

Laser
Rack

DSLAM

820b

820a

Ethernet
NID

ATU-R

FIGURE 9

CUSTOMER 1

CUSTOMER 2

CUSTOMER N 1030

1050

AGGREGATION UNIT 1010

PORT CONFIGURATION PROCESS 1012

PORT AGGREGATION PROCESS 1014

ADDRESS TABLE(S) 1060

SHARED LINK DE-AGGREGATION PROCESS 1016

MULTICAST GROUP MONITORING PROCES 1018

1040

OTHER AGGREGATION UNIT TABLE(S) 1019

ADMINISTRATION ENTITY 1092

ADDRESSING AND SERVICE PROVISION PLAN 1090

1020

ACCESS ROUTER 812

ACCESS CONTROL PROCESSES 1082

ACCESS CONTROL LIST 1083

VIRTUAL PRIVATE NETWORK ADDRESSING PROCESS 1084

ENCAPSULATION LOOKUP TABLE 1085

CLIENT DEVICE ADDRESSION TABLE 1089

1016'

GROUP SERVICE LEVEL PROCESS 1086

GROUP MONITOR PROCESS 1088

**FIGURE 10**

FIGURE 11

FIGURE 12
1200

| Bytes | 2 or 6 | 2 or 6 | 2 | 0-1500 | 0-46 | 4 |
|-------|--------|--------|---|--------|------|---|
| | Destination address | Source address | | Data | Pad | Checksum |
| | 1230 | 1240 | Length of data field 1250 | 1260 | 1270 | 1280 |

ADDRESS AND SERVICES MODEL

1090'

96 - 104 BITS FROM LAYER 2 (ETHERNET) HEADER

1310

VPN-ID (TO IDENTIFY CUSTOMER SOURCING OR RECEIVING THE TRAFFIC)

(ORGANIZATIONAL UNIVERSAL IDENTIFIER - OUI) ............24 BITS
(INDEX) ................................................ 32  BITS    1312

LOGICAL INGRESS PORT (TO MAINTAIN WHERE TRAFFIC ENTERED THE NETWORK)

GEOGRAPHIC LOCATION ................................. 16 BITS
PHYSICAL UNIT ....................................... .4 BITS
CARDINAL NUMBER ..................................... 12 BITS    1314

SERVICE IDENTIFIER (TO CONVEY A SERVICE LEVEL AGREEMENT AND
NETWORK REQUIREMENTS PER APPLICATION (FROM PACKET(S)))

QUALITY OF SERVICE ....................................8 BITS
CLASS OF SERVICE .................................. 8 OR 16 BITS
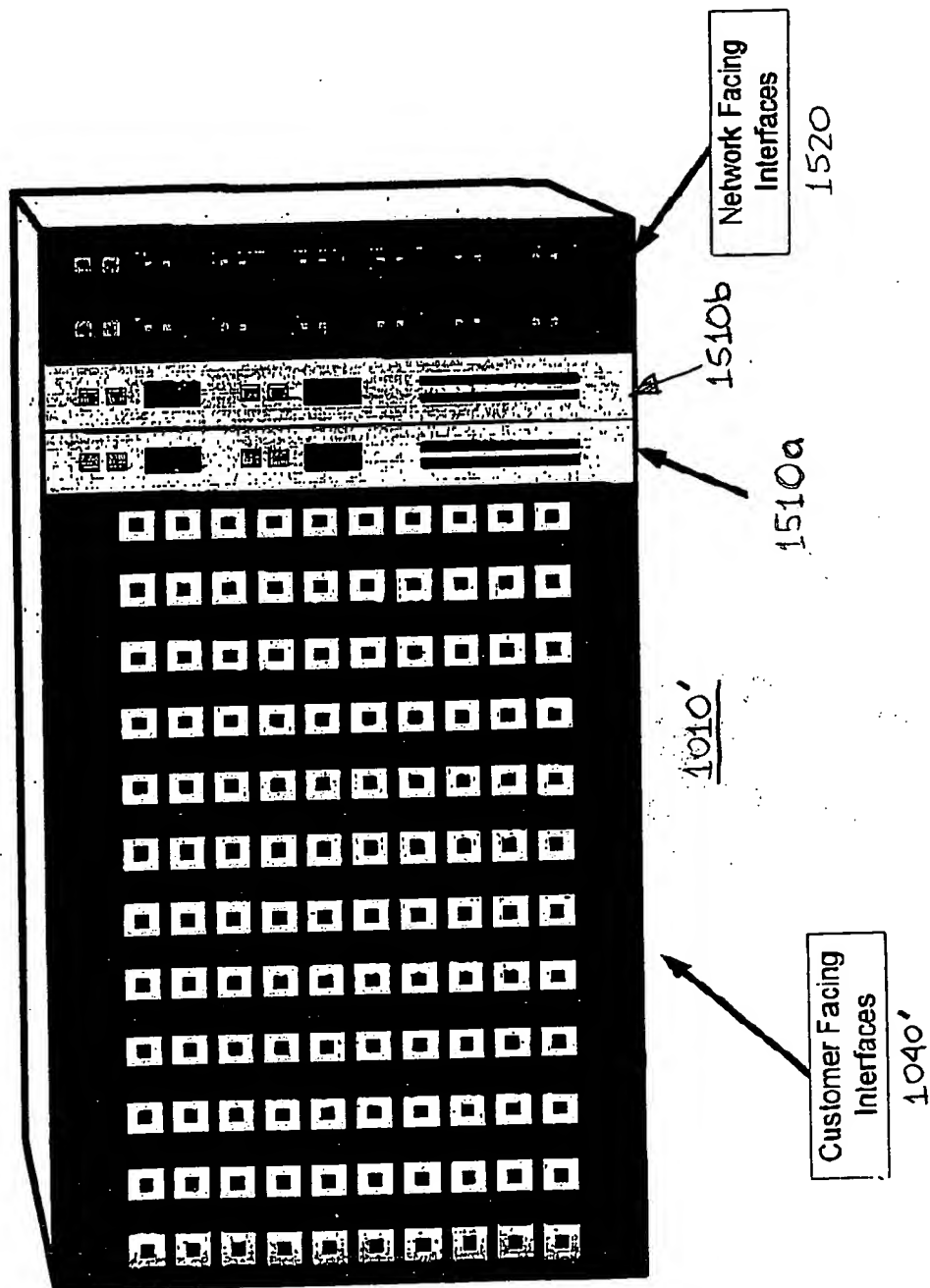
1320

FIGURE 13

1050'

1020'

GBE

MUX
10 Mbps
to
1 Gbps

100 10 Mbps
Ethernet
Full Duplex
Ports
per Gbe Port
OR
10 100 Mbps
Full Duplex
Ethernet
Ports
per GbE Port

For a 120 GbE Router:

120x100 = 12000 10Mb Customers

OR

120x10 = 1200 100Mb Customers

OR

60x100 = 6000 10Mb Customers
and
60x10 = 600 100Mb Customers
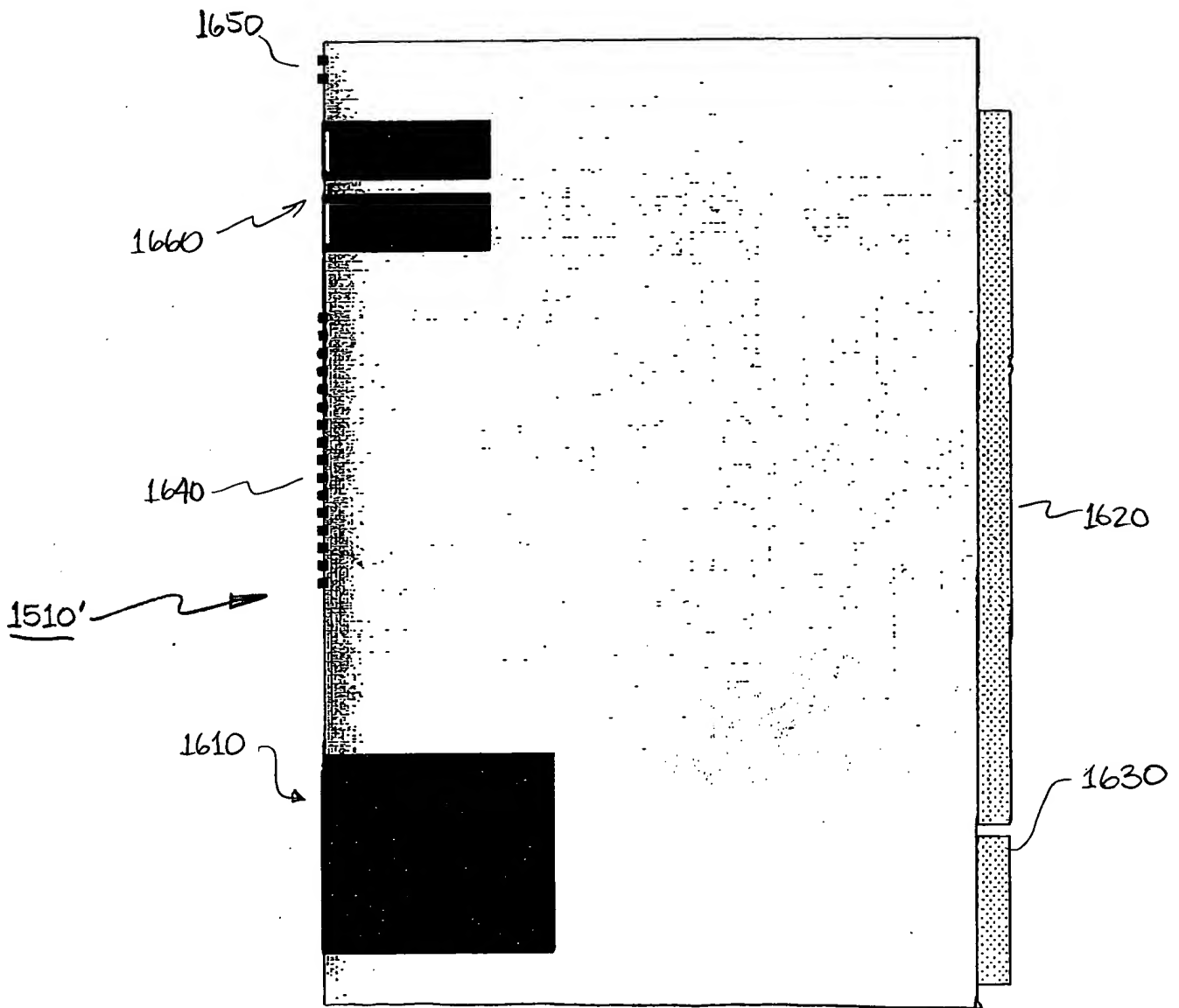
1040'

1010'

FIGURE 14

FIGURE 15

Network Facing
Interfaces
1520

1510b

1510a

1010'

Customer Facing
Interfaces
1040'

FIGURE 16

1700

1040"

1710

1720

FIGURE 17

FIGURE 18

**Assumes Globally Unique IP Addresses**

INGRESS

ACCESS ROUTER

Packet Type? — ARP
Other

1902
1904
1906b
1906b

Restamp L2 MAC Address Based on Ingress Context

1908 Forward packet unmodified

AGGREGATION DEVICE
1010'
812'

M1 1922
Forward Packet to SLA port — Rate Exceded — Service Level Agreement

Policy Enforcement 1920

Within Rate 1924

Apply Rate Limiting Policy 1918

Rewrite Type of Service Based on L2/3/4 1916

M2 1914
Forward Packet to Security port 1912

Denied — Policy Enforcement — Allowed

Apply Access Control List Policy Based on L2/L3 1910

Forward to Encapsulation Interface

1926 Lookup Destination based on L2/L3 ?

1928 Determine Type of Service by L2/L3/L4

1930 Encapsulate Packet in IP and set Type of Service Bits

1932 Forward Packet to Network Facing Interface

1934 Forward Packets to Network Based on Type of Service

PROBE 1940

EGRESS ACCESS ROUTER

Forward Packet to Security port 1964

Denied

Policy Enforcement 1962

M2

Apply Access Control List Policy Based on L2/L3 1960

1958 Forward Packet to Interface based on L2 Logical

1956 Lookup Destination L2 in ARP Table

1954 DeEncapsulate Packet

1952 Forward Packets to Encapsulation Interface

De

1966 Apply Rate Limiting Policy

Policy Enforcement 1968 — Rate Exceeded

Within Rate — Allowed

1972 Forward Packet to Network Facing Interface Physical

M1 1970 Forward Packet to SLA port

AGGREGATION DEVICE
1010''

1982 Forward packet based on L2 Destination

1984 Forward Packet

AGGREGATION DEVICE

FIGURE 19

LOGICAL PORT
CONFIGURATION METHOD

1012'

COUPLE CUSTOMERS
WITH KNOWN PORTS — 2010

ASSOCIATE A LOGICAL PORT WITH
A PHYSICAL PORT OR PHYSICAL
PORT LOCATION — 2020

PROVIDE A UNIQUE BIT
STRING (PACKET
INDEPENDENT CONTEXT
INFORMATION) TO THE
LOGICAL PORT — 2030

LEARN MAC ADDRESS OF
ATTACHED DEVICE (e.g., BY
ARP OR SNOOPING) — 2050

ASSOCIATE THE IP ADDRESS /
LOGICAL PORT WITH THE MAC
ADDRESS OF ATTACHED DEVICE(S) — 2060

RETURN — 2080

**FIGURE 20**

LOGICAL PORT TO AR LINK
AGGREGATION METHOD
1014'

DETERMINE PACKET-
DEPENDENT CONTEXT
INFORMATION (e.g., QoS) BASED
ON PACKET(S) (e.g., LAYER 3
AND/OR LAYER 4 INFORMATION)

2110

REMOVE SOME OR ALL
INFORMATION IN THE LAYER 2
HEADER  AND ADD UNIQUE BIT
STRING (OR CONTEXT
INFORMATION)

2120

AGGREGATE LOGICAL PORTS
TO DEFINE A LOGICAL TRUNK(S)
ON A HIGH BANDWIDTH
PHYSICAL LINK(S) TO AN
ACCESS ROUTER(S)

2130

2140

RETURN

# FIGURE 21

SHARED LINK
DE-AGGREGATION
METHOD
1016'

PLACE PACKET ON LOGICAL
PORT ASSOCIATED WITH
DESTINATION LAYER 2
(MAC) ADDRESS — 2220

CONVERT THE DESTINATION MAC
ADDRESS TO THAT OF DEVICE
ASSOCIATED WITH THE LOGICAL
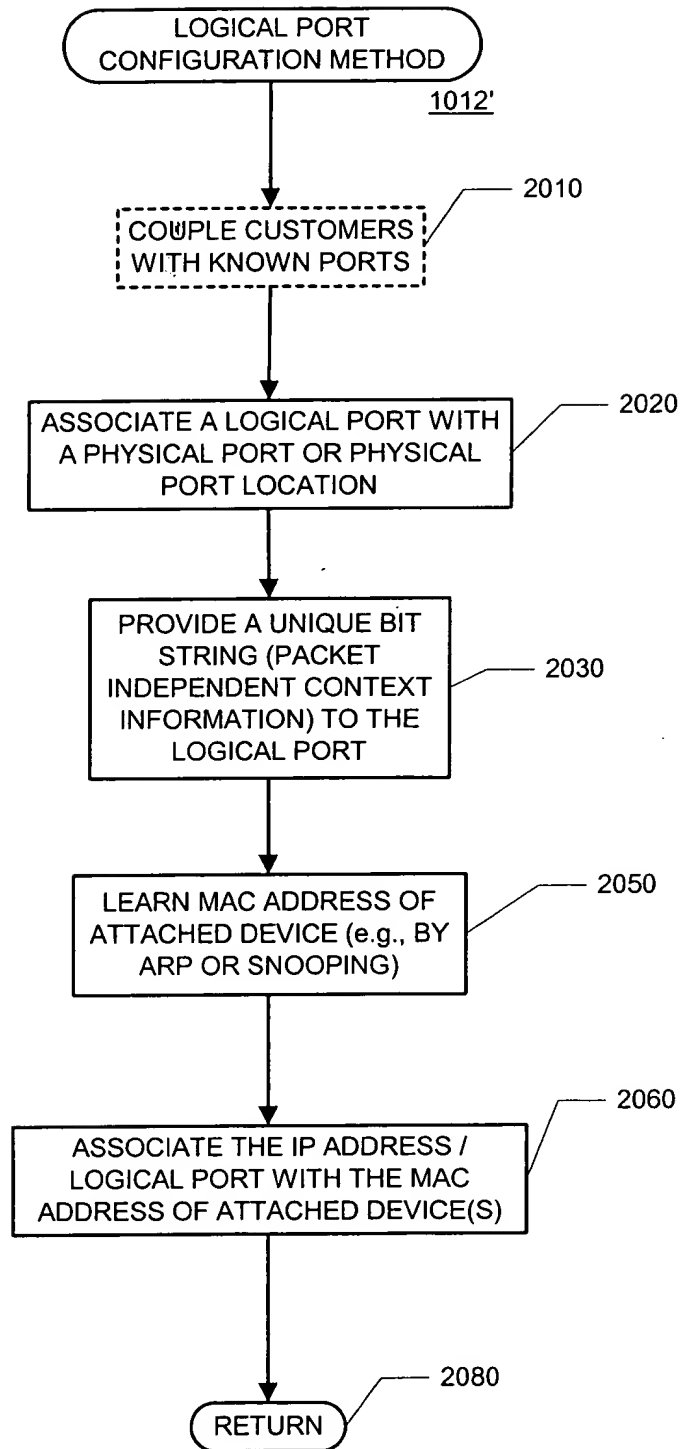PORT USING THE LAYER 3 (e.g.,
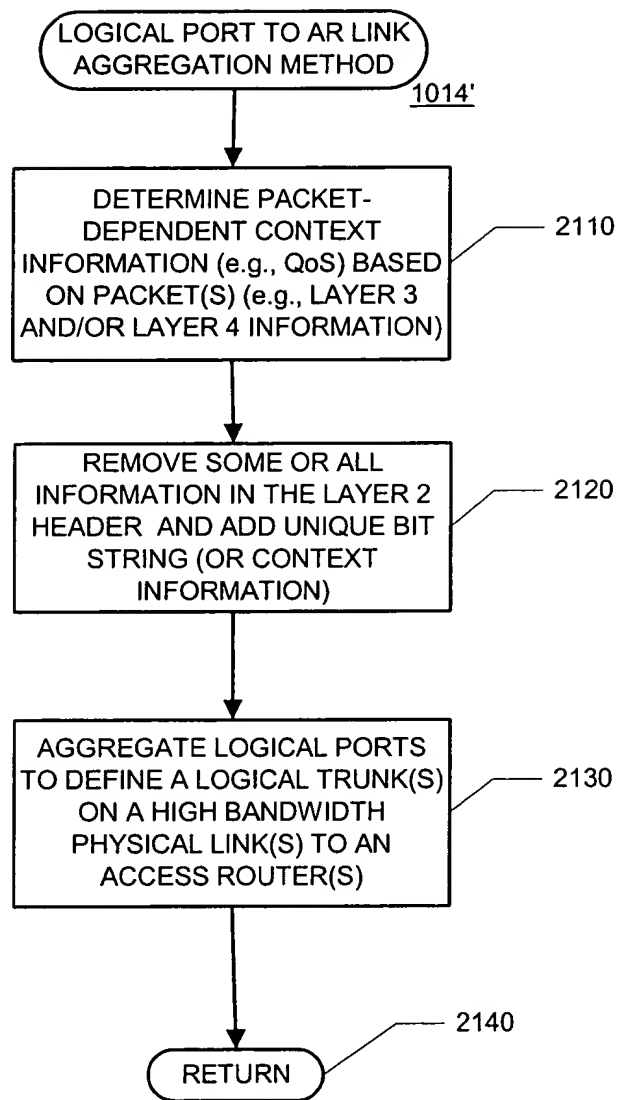IP) ADDRESS OF THE PACKET — 2230
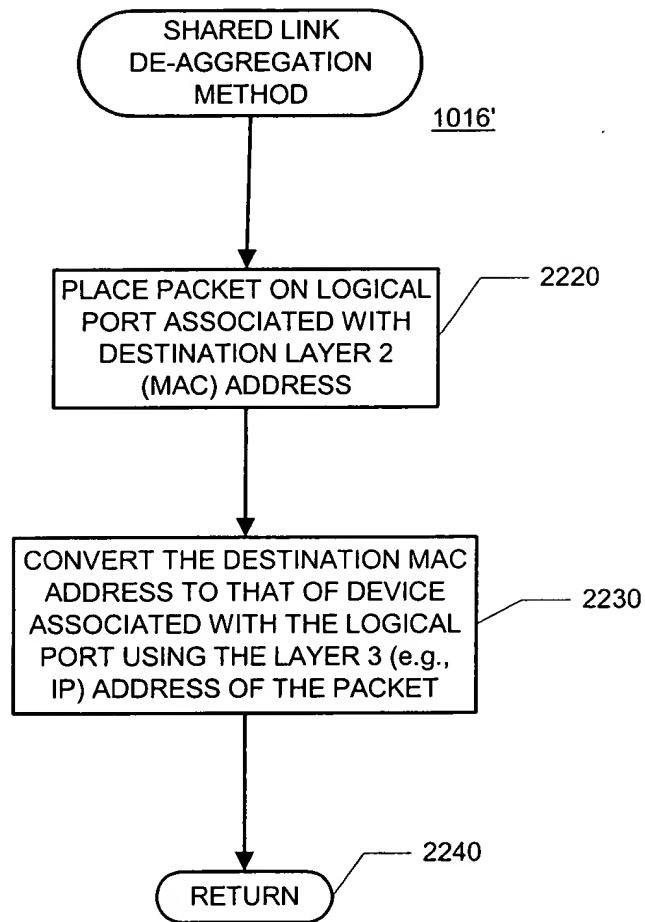
RETURN — 2240

## FIGURE 22

MULTICAST GROUP
MONITORING METHOD

1018'

EXAMINE BIT(S) OF THE UNIQUE BIT
STRING (OR CONTEXT INFORMATION)
RELEVANT TO MULTICASTING                    2310

2320

DO BITS
INDICATE PERMISSION        YES         ROUTE PACKET TO
TO JOIN MULTICAST                      PORT (ADD LOGICAL
GROUP?                                 PORT TO (JOIN)
                                       MULTICAST GROUP)

2330

NO

2340

RETURN

**FIGURE 23**


GROUP MONITORING METHOD

1088'

EXAMINE BIT(S) OF THE UNIQUE BIT
STRING (OR CONTEXT INFORMATION) AND/
OR L2/L3/L4 ADDRESSES RELEVANT TO           2410
GROUP TO BE MONITORED

2420

DO BITS
INDICATE GROUP TO BE       YES         COPY PACKET TO
MONITORED?                             "MONITORING"
                                       LOGICAL PORT

2430

NO

2440

RETURN

**FIGURE 24**

# Layer 2/3 Access Control

2510

2520 FIG. 25

2530

2540

| Context (3225, 3230, 3235, 3240, 3245, 3250) | L3 Source Address (3205) | L3 Destination Address (3215) | Action |
|---|---|---|---|
| **BA Services** | | | |
| Service Package #1 | ANY | Service Address #11 | DENY |
| Service Package #2 | ANY | Service Address #12 | DENY |
| Service Package #3 | ANY | Service Address #13 | DENY |
| **VRPN - No Internet Access** | | | |
| Context A | 100.100.100.0 /24 | 100.100.101.0 /24 | PERMIT |
| Context A | 100.100.100.0 /24 | 200.200.201.0 /24 | PERMIT |
| Context A | 100.100.100.0 /24 | 205.205.205.0 /24 | PERMIT |
| Context A | ANY | ANY | DENY |
| **VRPN - With Internet Access** | | | |
| Context B | 150.000.100.0/24 | 150.100.200.0/24 | PERMIT |
| Context B | 150.000.100.0/24 | 150.100.210.0/24 | PERMIT |
| Context B | 150.000.100.0/24 | 150.100.220.0/24 | PERMIT |
| **VPRN Internet Access** | | | |
| Context B | 900.900.900.0/24 | ANY | PERMIT |
| **Internet Access** | | | |
| Context C | BA Address Space | ANY | PERMIT |
| **Default Deny** | | | |
| ANY | ANY | ANY | DENY |

ACCESS CONTROL METHOD
1082'

EXAMINE BIT(S) OF ANY FIELD
(L2/L3/L4) OF THE ACL TABLE AND/
OR ANY PART OF THE CONTEXT
INFORMATION RELEVANT TO
ACCESS CONTROL
2610

2620

DO BITS
INDICATE PERMISSION TO
ACCESS?

YES → 2630 ROUTE PACKET

NO

2640 RETURN

**FIGURE 26**

**FIGURE 28**

GROUP SERVICE
LEVEL METHOD
1086'

EXAMINE BIT(S) OF FIELDS (L2/L3/L4) IN THE
ACL TABLE AND/OR ANY PART OF THE CONTEXT
INFORMATION RELEVANT TO SERVICE LEVEL
2810

2820a

DO BITS
INDICATE A SERVICE
LEVEL 1?

YES → 2830a FORWARD PACKET
TO QUEUE LEVEL 1

NO

2820b

DO BITS
INDICATE A SERVICE
LEVEL N?

YES → 2830b FORWARD PACKET
TO QUEUE LEVEL N

NO

2850 RETURN

## FIGURE 27A

```
        ╭──────────────────────────╮
        │   VIRTUAL PRIVATE NETWORK │
        │    ADDRESSING METHOD      │
        ╰──────────────────────────╯
                     │                      1084a'
                     ▼
  ┌──────────────────────────────────────────┐
  │  USE AT LEAST A PORTION OF THE            │── 2710
  │  ENCAPSULATION LOOKUP TABLE TO IDENTIFY   │
  │  MEMBERS OF A VIRTUAL PRIVATE NETWORK     │
  └──────────────────────────────────────────┘
                     │
                     ▼                      2720
         ◇────────────────────────◇
   NO    │   PACKET RECEIVED FROM  │
◄────────│   CUSTOMER (TO NETWORK)?│
         ◇────────────────────────◇
                     │ YES
                     ▼
  ┌──────────────────────────────────────────┐
  │  ENCAPSULATE NEW LAYER 3 OVER PACKET SO   │── 2730
  │  THAT THE CONTEXT INFORMATION (AND ANY    │
  │  OTHER INFORMATION IN THE PLACE OF THE    │
  │  LAYER 2 HEADER) IS PRESERVED             │
  └──────────────────────────────────────────┘
                     │
                     ▼
              ╭────────────╮  2735
              │   RETURN   │
              ╰────────────╯
```

## FIGURE 27B

```
        ╭──────────────────────────╮
        │   VIRTUAL PRIVATE NETWORK │
        │    ADDRESSING METHOD      │
        ╰──────────────────────────╯
                     │           1084b'
                     ▼               2740
         ◇────────────────────────◇
   NO    │   PACKET RECEIVED FROM  │
◄────────│   NETWORK (TO CUSTOMER)?│
         ◇────────────────────────◇
                     │ YES
                     ▼
           ┌──────────────────┐  2750
           │  DE-ENCAPSULATE  │
           └──────────────────┘
                     │
    2760             ▼
         ◇────────────────────────◇            ┌──────────────────┐
         │      ENTRY IN          │     NO     │  RESOLVE LAYER   │
         │  CLIENT DEVICE ADDRESSING│─────────►│  2 ADDRESS OF    │
         │       TABLE?           │            │  CLIENT DEVICE   │
         ◇────────────────────────◇            └──────────────────┘
                     │ YES                        2765
                     ▼                                   2770
  ┌──────────────────────────────────────────┐
  │  SET L2 SOURCE (FROM ACCESS               │
  │  ROUTER EGRESS PORT) AND L2               │
  │  CLIENT DEVICE DESTINATION (FROM          │
  │  CLIENT DEVICE ADDRESSING TABLE)          │
  └──────────────────────────────────────────┘
                     │
                     ▼           2780
           ┌──────────────────┐
           │    FORWARD       │
           │    THE PACKET    │
           └──────────────────┘
                     │
                     ▼           2790
              ╭────────────╮
              │   RETURN   │
              ╰────────────╯
```

"COTE90" 057/229580

| LOGICAL PORT | VPN-OUI | VPN-INDEX | CUSTOMER - ID | SERVICE LEVEL | MULTICAST ACL GROUP | QoS PROFILE | VPI | VCI | PVC | ETHERNET PORT |
|---|---|---|---|---|---|---|---|---|---|---|
| . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . |

2910 / 2920 / 2930 / 2940 / 2950 / 2960 / 2970 / 2982 / 2984 / 2986 / 2988

**FIGURE 29**

1060'

| LOGICAL PORT | AGG MAC ADDRESS | IP ADDRESS | SUBNET MASK | CLIENT MAC ADDRESS |
|---|---|---|---|---|
| . . . | . . . | . . . | . . . | . . . |

3010 / 3020 / 3030 / 3040 / 3050

**FIGURE 30**

1060"

| MULTICAST ACL GROUP | MULTICAST ADDRESS | SUBNET MASK | VPN-OUI | VPN-INDEX |
|---|---|---|---|---|
| . . . | . . . | . . . | . . . | . . . |

3110 / 3120 / 3130 / 3140 / 3150

**FIGURE 31**

1019'

| SOURCE IP ADDRESS | SOURCE SUBNET MASK | DESTINATION IP ADDRESS | DESTINATION SUBNET MASK | VPN-OUI | VPN-INDEX | PROTOCOL | L4 PORT | TOS | SERVICE CENTER |
|---|---|---|---|---|---|---|---|---|---|
| 3205 | 3210 | 3215 | 3220 | 3225 | 3230 | 3235 | 3240 | 3245 | 3250 |
| . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . | . . . |

LAYER 3 — LAYER 2 — LAYER 4 — LAYER 3 — LAYER 2

**FIGURE 32**

1083'

| IP ADDRESS | SUBNET MASK | VPN-OUI | VPN-INDEX | (MPLS or IPinIP) DESTINATION (OF EGRESS ROUTER) |
|---|---|---|---|---|
| 3310 | 3320 | 3330 | 3340 | 3350 |
| . . . | . . . | . . . | . . . | . . . |

**FIGURE 33**

1085'

| IP ADDRESS | VPN-OUI | VPN-INDEX | CLIENT MAC ADDRESS |
|---|---|---|---|
| 3410 | 3420 | 3430 | 3440 |
| . . . | . . . | . . . | . . . |

**FIGURE 34**

1089'

# FIGURE 35

3500

| 3520 | | | | | | |
|---|---|---|---|---|---|---|
| L2 (MAC) DESTINATION ADDRESS (48 BITS) | L2 (MAC) SOURCE ADDRESS (48 BITS) | 802.1Q VLAN E TPID | 802.1Q VLAN TAG ID | LENGTH, ETC. | | |
| 3522 | 3524 | 3525 | 3526 | 3527 | | |

| 3530 | | | | |
|---|---|---|---|---|
| PROTOCOL 618' | PORT 3532 | L3 SOURCE ADDRESS 622' | L3 DESTINATION ADDRESS 624' | TYPE OF SERVICE 606' |
| DATA 3510 | | | | |

# FIGURE 36

## FIGURE 37

3700

**3716**

**3760**

| L2 (MAC) DESTINATION ADDRESS (48 BITS) 3740 | L2 (MAC) SOURCE ADDRESS (48 BITS) | | ETHER TYPE |
|---|---|---|---|
| L3 SOURCE ADDRESS (INGRESS ACCESS ROUTER - TABLE) 3710 | L3 DESTINATION ADDRESS (EGRESS ACCESS ROUTER - TABLE) 3720 | | TYPE OF SERVICE (IN NETWORK) 3750 |
| VPN-INDEX (32 BITS) | QoS (8 BITS) | VPN-OUI (24 BITS) | LOGICAL INGRESS PORT (32 BITS) | 802.1Q VLAN E TPID | CoS (16 BITS) | LENGTH, ETC. |
| PROTOCOL 618' | PORT 3532 | L3 SOURCE ADDRESS 622' | L3 DESTINATION ADDRESS 624' | TYPE OF SERVICE 606' |

DATA

3510